Use of District Energy Modelling and Stakeholder Engagement in Developing Decarbonisation Strategies

Susan Pierce1, Lorenzo De Donatis1, Fabiano Pallonetto2, Giovanni Tardioli1
1Integrated Environmental Solutions (IES) R&D, Dublin, Ireland
2IVI Institute - Maynooth University, Kildare, Ireland

Abstract
This paper presents an approach to develop a decision-making support tool for the decarbonisation of urban areas. A calibrated district energy model has been created and used to assess the impact of potential decarbonisation strategies for the heat and electricity sectors. An Irish university campus has been selected as a case-study. The analysis concludes that the campus can achieve a 10% reduction in carbon dioxide emissions through improved use of existing systems at district level. The introduction of new generation units could further reduce emissions by up to 26%.

Key innovations
• The combination of district energy modelling and stakeholder engagement to ensure that the resulting strategy is feasible for the community.
• The aim of developing and employing an energy model to guide an urban district to full decarbonisation.

Practical implications
Engagement with the local community and stakeholders must be considered in district energy modelling to translate the simulation results into a feasible decarbonisation strategy.

Introduction
The decarbonisation of urban areas will play a vital role in tackling climate change and meeting future emissions targets. Densely populated districts, towns and cities are among the most challenging to develop sustainably (Neij et al., 2015). They are typically large energy consumers in the electricity, heat and transport sectors, with limited availability of space and a diverse range of activities and building stock. In such communities, merging the objectives and requirements of different stakeholders is one of the main challenges faced. Simulation at urban scale can help to overcome this by driving decision-makers towards justified routes, quantifying the impact of specific choices (Sofia et al., 2020). By encouraging analysis that goes beyond a single building scale, new opportunities can be exploited, leading to low-carbon, energy efficient districts (Cajot et al., 2017).

Technologies aimed at decarbonisation are continuously being developed and brought to the market, however, significant barriers exist which are slowing their uptake and implementation (Papdis and Tsatsaronis, 2020). Uncertainty regarding the effectiveness, suitable application and monetary costs and savings of these technologies means that consumers are reluctant to invest. This is further evidence of the need for decision-making support tools.

A highly efficient, technically equipped, and smarter building stock could be the cornerstone of a decarbonised energy system (Al Dakheel et al., 2020). Buildings can be at the forefront of providing flexibility to the energy system through energy production, control, storage and demand response, which could also integrate charging stations for electric vehicles. This action's full impact requires a systemic upgrade of the building stock to efficient buildings, districts and ecosystems. Within the energy transition, smart buildings and smart grids are playing a critical role, meanwhile ICT technologies are the drivers of such change. In order for Europe to benefit from the new opportunities that will be created in the energy transition, the EC Digital Single Market (DSM) strategy underlines the need to foster interoperability and seamless data exchange for the Internet of Things (IoT) through existing standards. The interoperability and data sharing between energy vectors and services will ensure integrating local energy systems with smart grids, increasing renewable energy and energy efficiency. The IoT will set up new ecosystems that cut across vertical areas and create new markets for hardware (connected devices), software (IoT platforms and systems) and services (IoT applications) while facilitating energy planning (Jia et al., 2019).

Energy planning and decarbonisation at an urban scale is challenging. This is due to the multiple energy systems and sectors involved, along with the variety of different energy uses and stakeholders. Despite this challenge and the importance of developing solutions, the modelling of these district energy systems is under-represented in research (Klemm and Vennemann, 2021).

Various studies have been carried out on the approaches to modelling district-scale energy systems and the software available (Allegrini et al., 2015). However, there is a need for further research into the practical application of these methodologies for urban planning (Simoes et al., 2019). This paper presents a unique approach to district energy modelling, engaging with stakeholders throughout to determine the scenarios for analysis, present and discuss results, and to adapt the modelling approach based on their feedback.
In this paper, the Belfield campus at University College Dublin (UCD), Ireland’s largest university campus, has been selected as the urban area for analysis. A virtual model of the campus, including 35 buildings and the associated electricity and heating networks, has been created and calibrated using building management system (BMS) data. The model uses real metered data to create the building demand profiles and simulates the energy generation to meet this demand. The resulting generation depends on the demand, the network configuration and the generation assets and their properties. The baseline model has been calibrated to ensure that the simulated generation matches that of the real campus.

A district heating network (DHN) runs through the campus, partially or fully meeting the heat demand of each of the 16 buildings within the site. As the university aims for full decarbonisation by 2050, the calibrated model has been used to determine the impact of specific decarbonisation measures on the campus carbon dioxide (CO₂) emissions. The measures include control strategies, alternative network configurations and the installation of new energy generation units.

The hybrid approach used for the analysis has given the work the possibility to merge real and simulated data through the interaction of various pieces of software communicating together. This has given strength and reliability to the future development scenarios, being based on a virtual baseline model, the behaviour of which matches that of the actual campus.

The work in this paper is focused on decarbonisation at community-level, with a particular emphasis on stakeholder engagement throughout the process. The results of this analysis will be used to inform the Energy Master Plan for the UCD Sustainable Energy Community (SEC). The objective of this work is to analyse the impact of proposed decarbonisation measures and to identify, and justify, feasible next steps for the campus. The scenarios investigated were introduced and adapted on an ongoing basis, informed by the results of previous iterations and feedback received from the stakeholder engagement process.

**Methodology**
This section describes the steps undertaken to create a virtual model of the campus and the strategy employed to investigate the impact of selected low-carbon measures. An overview of the modelling approach is first provided, including information on the software employed. Details of the data collection process, baseline model creation and calibration, and the scenario testing strategy, are included in subsequent sections.

**Modelling overview**
Given the objectives of the work undertaken, it was necessary to use a combination of tools from Integrated Environmental Solutions (IES). The Intelligent Control and Analysis (iSCAN) platform allowed for the metered data to be collected, verified, and integrated into the model. The model itself was created in the Intelligent Virtual Network (iVN), which could then be used to assess the impact of selected low-carbon measures.

Stakeholder engagement played a significant role throughout the project, providing insights and feedback on the model requirements and the strategies for scenario testing.

**Data requirement**
The Belfield campus of UCD is unique in that it contains a BMS with extensive metering equipment. The electricity and heating demand of each campus building is measured and recorded in fifteen-minute intervals, which can then be accessed and downloaded through an online dashboard. Metered data is also available for energy generation units.

The metered data has been used to create electricity and heat demand profiles for each of the buildings. Data from 2019 was chosen as it is the most complete and recent set of meter readings, therefore being representative of the current campus energy performance. The generation profiles for both heat and electricity assets were collected for calibration purposes.

Through engagement with UCD Estate Services, information was obtained on the generator control and dispatch strategy for the DHN. The campus development plan provided information on the current campus and future plans (UCD, 2016). Regular meetings were held with campus stakeholders to discuss project requirements and update on progress. Results were presented and discussed as they were obtained, allowing for stakeholder involvement in selecting plausible scenarios, making changes to the analysis, and evaluating the feasibility of interventions.

**Baseline model**
The layout of the campus was imported into the iVN software from the OpenStreetMap (OSM) database. The 3D campus model can be seen in Figure 1, in which the yellow buildings are those included in the analysis.

![Figure 1: iVN model of UCD Belfield campus – 3D view](https://example.com/figure1.png)

The weather file DublinIWEC.fvt (International Weather for Energy Calculations) was selected, containing 18 years of recorded data from 1982 to 1999. As the electricity and heat demand profiles for the year 2019 were known, they were assigned directly to the buildings, without the need of running energy simulations at building level and thus address the accuracy and reliability of geometries and thermal properties.

The heat and electricity demand data for each building were downloaded from the BMS database as CSV files. The CSV files were then uploaded manually to the iSCAN platform to create the demand profiles. The visualise tool
allowed for the data to be verified, namely, checking for seasonal trends and data gaps. An example can be seen in Figure 2, where the heat demand of a large energy consumer is shown monthly for 2019. As expected, the peak demand occurs during the winter months, with a sharp decline entering the summer period, attributed to both the change in weather and the closing of the typical academic year. The visual below the graph indicates the quality of the data, specifically, the presence or absence of data for each day of the year. As each data point is green, it means that the data set is complete for the entire year, with no missing readings. A similar analysis was carried out for each heat and electricity demand profile.

Once the data has been verified, the demand profiles were imported into the iVN and assigned to the relevant buildings, shown in Figure 3 in a 2D view. Each building was assigned an electricity, DHN and local heating demand profile as appropriate, with energy demand data at fifteen-minute intervals.

The DHN forms the centre of the campus energy network, through which heat is supplied by six generation units located in the campus energy centre. Table 1 contains the details of the current generators, including their heating capacity, fuel type and their position in the assigned dispatch schedule. Two combined heat and power (CHP) units are the preferred generation units, while the biomass unit is currently off. Eleven buildings rely on the DHN to meet their entire heating demand, while five more buildings have some heat supplied by local generation units, typically gas boilers.

### Table 1: DHN energy centre generation units

<table>
<thead>
<tr>
<th>Name</th>
<th>Capacity (MW)</th>
<th>Fuel</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP 1</td>
<td>1.2</td>
<td>Gas</td>
<td>1</td>
</tr>
<tr>
<td>CHP 2</td>
<td>0.8</td>
<td>Gas</td>
<td>2</td>
</tr>
<tr>
<td>Boiler 1</td>
<td>1.7</td>
<td>Gas</td>
<td>3</td>
</tr>
<tr>
<td>Boiler 2</td>
<td>1.7</td>
<td>Gas</td>
<td>4</td>
</tr>
<tr>
<td>Boiler 3</td>
<td>5.8</td>
<td>Gas</td>
<td>5</td>
</tr>
<tr>
<td>Biomass Unit</td>
<td>0.95</td>
<td>Biomass</td>
<td>6</td>
</tr>
</tbody>
</table>

From consultation with UCD Estate Services, it was found that the generation units are dispatched manually based on the load requirements, a process which involves load searching and heat dumping, as the CHP units are never run on part-load. Therefore, the dispatch schedule modelled at the iVN heat node is that which best represents the strategy of the BMS manager. The emissions factors for gas, biomass and grid electricity have been included in Table 2, with values obtained from the Sustainable Energy Authority of Ireland (SEAI, 2019).

### Table 2: Emissions factors of fuel types

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Emissions Factor (kgCO₂/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>0.203</td>
</tr>
<tr>
<td>Biomass</td>
<td>0.025</td>
</tr>
<tr>
<td>Electricity (Grid)</td>
<td>0.409</td>
</tr>
</tbody>
</table>

The buildings that are not connected to the DHN have local gas boilers installed to supply their heat demand. Two large energy consumers, the student centre and the science district, also have local CHP generators. Renewable electricity is generated on campus through two roof-top solar photovoltaic (PV) installations, each with a 10 kW capacity. The completed iVN baseline model can be seen in Figure 5. An initial check was carried out to ensure that there was a sufficient supply of heat and electricity to meet the demand at each 60-minute time-step.
Calibration of the iVN model involved comparing the simulated production of the main campus generators with the measured data. In this case, the two CHP units in the energy centre were chosen due to their role as major energy providers for the campus and the availability of metered data. The output of the CHP units was simulated for 2019 and compared to the metered data. Calibration has been carried out on a monthly basis using the Mean Bias Error (MBE) (1).

\[ MBE(\%) = \frac{\sum_{\text{Period}}(S-M)\text{Interval}}{\sum_{\text{Period}}M\text{Intervat}} \times 100 \] (1)

The MBE for the CHP generation was calculated to be -3.53%, which is within the acceptable range of ±5% (U.S. DOE, 2015).

**Scenario testing**

Once the baseline model had been calibrated, it could be used to test potential approaches to the decarbonisation of the campus. The scenarios were developed through consultation with stakeholders and the analysis of the baseline model results.

The decarbonisation of the DHN was identified as a key area of interest for stakeholders. Connecting new low-carbon generators to the network could achieve significant savings, while limiting disruption to campus and building services (Connolly, 2014). Stakeholders also highlighted the importance of building upgrade and retrofit for campus decarbonisation, which facilitated the exploration of this additional scenario (Menassa, 2014). Many of the existing buildings were constructed in the mid- to late-1900s, with building energy ratings (BER) across the campus ranging from A-rated down to G-rated.

The model has been used to investigate six scenarios, three of which have variants that differ based on generator capacity or dispatch schedule. The first five scenarios aim to identify feasible next steps for the campus in the short-term. The ideal scenario would be one in which the greatest campus-wide emissions savings could be achieved in the shortest timeframe, while also minimising disruption to campus activities. The intervention introduced in Scenario 1 has been maintained throughout these five scenarios as it is outlined in the current campus plans. The first four scenarios focus mainly on the provision of heat. Following an analysis of these interventions, scenario 5 was created to increase renewable and reduce electricity emissions. From stakeholder consultation, a sixth scenario was then introduced, which carries out a high-level analysis of the total impact of widespread building retrofit over the coming years.

- **Scenario 1**: The gas boilers in the buildings connected to the DHN are removed and the DHN is used to meet their entire heat demand.
- **Scenario 2**: The biomass generator is turned on and connected to the DHN. Scenario 2A places the biomass unit at the top of the priority list, while Scenario 2B places it below the two gas-powered CHP units.
- **Scenario 3**: The current biomass generator is replaced by a biomass CHP unit, with a rated heat output of 900 kW and a rated electricity output of 600 kW. This new CHP generator is given top priority in the dispatch schedule.
- **Scenario 4**: The new biomass CHP generator is added and the current biomass unit maintained. Scenario 4A investigates the impact of prioritising the use of biomass as a fuel, with the biomass CHP at number one, followed by the heat-only unit. Scenario 4B moves the biomass boiler further down the priority list, meaning that all CHP units are dispatched first, then heat-only generators.
- **Scenario 5**: A solar PV installation of 3 MW, the calculated campus potential, is added to the network. The capacity of solar PV has been calculated using the roof area of the 35 buildings, a utilisation factor of 0.3 and a capacity factor of 0.102 kWp/m² (Horan et al., 2019). This scenario builds on Scenario 4B.
- **Scenario 6**: The demand profiles of the 35 buildings are adjusted to represent a B1-rated version of that facility, where they are not already at this rating or above. To investigate the impact of the refurbishment, the demand profile of a B1-rated building has been converted to kWh/m² at each timestep. The new demand profiles for the buildings were then created based on their internal floor area. Scenario 6A considers this refurbishment as the only variation from the baseline. The impact of adding a heat pump to the DHN of the refurbished campus and giving it top priority has been assessed in Scenario 6B and Scenario 6C, with 1 MW and 2 MW heat pump added respectively.

**Results and discussion**

This section contains the results of both the baseline and scenario analyses. In each case, the focus is on the CO₂ emissions produced by the campus in 2019. The CHP units are considered to be operating a bottoming cycle, where heat is the primary output (Al Moussawi, 2016). As a result, all of the CO₂ emissions from the CHP units are counted under heating.
Baseline analysis
The calibrated campus model has been used to carry out a baseline analysis of the energy performance for 2019. Three levels of analysis were carried out:
1. A high-level analysis of the overall campus energy consumption and CO₂ emissions, including the breakdown between heat and electricity.
2. A building-level analysis to identify key energy consumers.
3. A generator-level analysis to understand the level of CO₂ emissions from each unit, considering their outputs.

The simulation results at campus level are shown in Table 3. Heat generation is the main contributor to both energy consumption and emissions production, with 56% and 65% of the totals respectively. Through the use of CHP units, 46% of the campus electricity demand is being supplied without extra emissions production. Less than 1% of the total electricity demand is met by the two 10 kW PV installations, the remaining portion being imported from the grid.

Table 3: Campus baseline simulation results

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Energy (GWh)</th>
<th>CO₂ Emissions (tons CO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>52.09</td>
<td>14,322</td>
</tr>
<tr>
<td>Heating</td>
<td>29.18</td>
<td>9,309</td>
</tr>
<tr>
<td>Electricity</td>
<td>22.91</td>
<td>5,023</td>
</tr>
</tbody>
</table>

The building-level analysis involved ranking the facilities based on the emissions produced as a result of their demand for electricity and heat. It was found that six of the top ten buildings are connected to the DHN, indicating that decarbonising generation in the DHN energy centre would target these key emitters and result in CO₂ emissions reduction.

Moving to generator-level, despite the CHP units being at the top of the priority list in the DHN energy centre, one of the gas boilers is still producing the most heat. This is due to the decision to never run the CHP units at part-load. As a result, during the summer months, demand at each timestep is often insufficient to meet the minimum threshold for CHP use and the boiler is turned on instead. Increasing the load on the DHN, by connecting more buildings or removing local boilers from current buildings, would increase the baseline demand. Combining this with the installation of additional lower-carbon generation to meet the increased demand during heating dominated months could have a positive impact on emissions overall.

Scenario analysis
Each of the scenarios has been modelled in the iVN and the simulation run for the year 2019. The results have been compared in terms of the CO₂ emissions produced to meet the campus electricity and heating demands. Figure 6 shows the reduction in total emissions associated with each scenario.

Scenario 1 shows that a 4% reduction in CO₂ emissions could be achieved by allowing the DHN to supply the full heating demand of the buildings connected to its network. The increase in demand on the DHN means that the CHP units can be used more frequently, resulting in displaced grid electricity and a 26% reduction in electricity related emissions. However, the extra demand on the DHN during the winter months means that the larger, less efficient boiler is used more often, increasing the heating emissions. Overall an emission reduction can be achieved and this decarbonisation measure was maintained throughout the first five scenarios.

Turning on the current 0.95 MW biomass unit in scenario 2A and 2B achieved an emissions reduction between 9% and 11%, depending on the control sequence in the energy centre. The breakdown of emissions can be seen in Figure 7. Despite biomass having a lower emissions factor than natural gas, the cogeneration aspect of the CHP units makes them favourable in terms of overall emissions reduction. In terms of decarbonisation, displacing imported electricity with the CHP units is more beneficial than switching to lower carbon fuels that provide only heating. The benefit of the biomass boiler is most prominent in the summer months, when there is insufficient demand to run the CHP units at full capacity. The biomass generator meets the demand previously supplied by a gas boiler, resulting in lower CO₂ emissions.

![Figure 6: Percentage reduction in total CO₂ emissions in each scenario from baseline](https://doi.org/10.26868/25222708.2021.30703)
Scenario 3 investigates the impact of replacing the biomass boiler with a cogeneration unit to improve the overall efficiency. From stakeholder consultation, a new biomass CHP unit would be selected first for generation whenever possible. Interestingly, a further emissions reduction of only 1% was achieved compared to the original boiler. This is due to the lower electrical efficiency of the biomass CHP compared to the gas CHP units currently installed. Although greater savings are made in heating related emissions with the biomass CHP compared to the heat-only biomass unit, the electricity savings are much lower. Adding the new biomass CHP and retaining the current biomass boiler, as in scenario 4A and 4B, achieved an overall reduction in emissions of approximately 17%, with only a small difference depending on the dispatch schedule.

The biomass CHP and the solar PV installation in scenario 5 displaced 29% of the imported electricity. A total emissions reduction of 26% was achieved, broken down into savings of 25% heating and 29% electricity related emissions.

Throughout the first five scenarios the building energy demand remained constant. Carrying out a refurbishment to achieve a minimum BER rating of B1 across all buildings reduced the total energy demand for the year from 52.09 GW to 41.74 GW, a reduction of approximately 20%. The change in the campus heat demand over the year can be seen in Figure 8. This refurbishment alone would achieve an overall CO2 emission saving of 10%.

The addition of the 1 MW and 2 MW heat pumps in the DHN energy centre resulted in an emissions reduction of 12% and 19% respectively.

Conclusion

The work undertaken has focused on the application of district level energy modelling and stakeholder engagement in developing tailored and evidence-based decarbonisation strategies. In the current work, the use of heterogeneous historical data from all the buildings in the district and the stakeholder consultation towards large-scale electrification of thermal loads and more sustainable
energy systems has transformed a formal consultation into an innovative, collegial decision process because of the calibrated modelling and scenario analysis performed at the community level rather than at building management level. The innovative process led users, building managers, and policymakers to assess the analysis from the environmental, cost and energy perspective, participate in the discussion, and contribute as decision-makers, or just with sustainable behaviours to support the management.

The analysis showed that allowing the current DHN to operate closer to its full potential would have almost the same impact on CO$_2$ emissions as carrying out a refurbishment to bring all buildings to a minimum B1 BER rating. Although improving the energy efficiency of the building stock will play a key role in achieving full decarbonisation, the investigation highlights the need for optimisation of existing systems and networks. In this way, significant emissions savings can be made with low or no cost and disruption to services.

Through improved use of the DHN and the installation of a new biomass CHP, emissions could be reduced by up to 17%. When coupled with a solar PV installation to tackle electricity emissions directly, the savings would increase to 26%. An alternative strategy of widespread retrofit and a heat pump installation on the current DHN would achieve a 19% emissions reduction.

A fundamental requirement for the decarbonisation process is the availability of detailed historical energy consumption and occupant behaviour data. The centralised data repository available for the UCD Campus has facilitated the carbon footprint analysis and detailed model development. Additional data on staff and students commuting, parking occupancy and internal working schedules have been essential for calibrating the model and exploring the impact of different measures. It should be noted that some of the decarbonisation measures have been selected and analysed after consultation with the UCD Energy Estates team responsible for the campus facilities and after the evaluation of specific Irish policies for the public sector. In such an endeavour towards a more sustainable future, a lesson learnt is the importance of discerning and evaluating different perspectives: occupants, user behaviour, policies and local community guidelines.

The technology used to enable this cooperation has led to a holistic approach where different stakeholders could, directly or indirectly, collaborate to enrich the model, aimed at creating a unique digital twin of the university, with the potential of predicting the campus behaviour over time and under different possible scenarios (Woods et al., 2019). This was made possible also by the use of beta-versions of the simulation tools, thanks to a bi-directional feedback process aimed at fulfilling the project scope while also integrating the broader stakeholder perspective into possible considerations for future software development.

Future work will involve the finalisation of the UCD SEC Energy Master Plan, including details of the current campus community, along with the energy demand and generation, a register of opportunities containing the results of the scenario analysis, and a list of the suitable projects selected for the campus. A key attribute of the SEC programme and the Energy Master Plan is that the objectives set are feasible and are agreed among the stakeholders. Therefore, stakeholder engagement and involvement throughout the process is vital if the community is to commit to implementing the interventions and improve their energy efficiency. The work undertaken has provided UCD with the means to explore a variety of decarbonisation strategies at district level. Future work will aim to extend the timeframe of the analysis to guide the campus to full decarbonisation.

Acknowledgements

The work has been undertaken through collaboration and engagement with Integrated Environmental Solutions (IES) Ltd., University College Dublin (UCD) Sustainable Energy Community and UCD Estate Services.

Nomenclature

<table>
<thead>
<tr>
<th>UCD</th>
<th>University College Dublin</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHN</td>
<td>District Heating Network</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>SEC</td>
<td>Sustainable Energy Community</td>
</tr>
<tr>
<td>IES</td>
<td>Integrated Environmental Solutions</td>
</tr>
<tr>
<td>iSCAN</td>
<td>Intelligent Control and Analysis</td>
</tr>
<tr>
<td>iVN</td>
<td>Intelligent Virtual Network</td>
</tr>
<tr>
<td>BMS</td>
<td>Building Management System</td>
</tr>
<tr>
<td>CHP</td>
<td>Combined Heat and Power</td>
</tr>
<tr>
<td>MBE</td>
<td>Mean Bias Error</td>
</tr>
<tr>
<td>m$_i$</td>
<td>Measured output</td>
</tr>
<tr>
<td>s$_i$</td>
<td>Simulated output</td>
</tr>
<tr>
<td>N</td>
<td>Number of data points in the interval</td>
</tr>
<tr>
<td>BER</td>
<td>Building Energy Rating</td>
</tr>
<tr>
<td>PV</td>
<td>Photovoltaic</td>
</tr>
</tbody>
</table>

References


urban scale. *Sustainable Cities and Society* 30, 223-236.


Intelligent Control & Analysis (iSCAN), Integrated Environmental Solutions Ltd., Glasgow; software available at: [https://www.iesve.com/icl/iscan](https://www.iesve.com/icl/iscan)

Intelligent Virtual Network (iVN), Integrated Environmental Solutions Ltd., Glasgow; software available at: [https://www.iesve.com/icl/ivn](https://www.iesve.com/icl/ivn)


